(12) UK Patent Application (19) GB (11) 2 097 529 A

(21) Application No 8206027
(22) Date of filing 2 Mar 1982
(30) Priority data
(31) 8113073
(32) 28 Apr 1981
(33) United Kingdom (GB)
(43) Application published
3 Nov 1982
(51) INT CL³
G01N 21/49
(52) Domestic classification
G1A A4 C12 C13 C9 D10 DM G10 G11 G12 G13 G16 G17 G6 G7 G8 G9 P10 P18 R6 R7 S12 S4 S5 T15 T22 T2
(56) Documents cited
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(58) Field of search
G1A

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(54) **Detecting oil in water**

(57) An oil in water detector arrangement wherein the response signal is substantially independent of oil type. Scattered light signals for an incident beam from a source 21 directed into a scatter cell are measured at two scatter angles (21, 22) by detectors $D_1$ and $D_2$ and oil concentration value is calculated from the difference between the twı gnals. This obviates the need for recalibration of the arrangement for different oils.

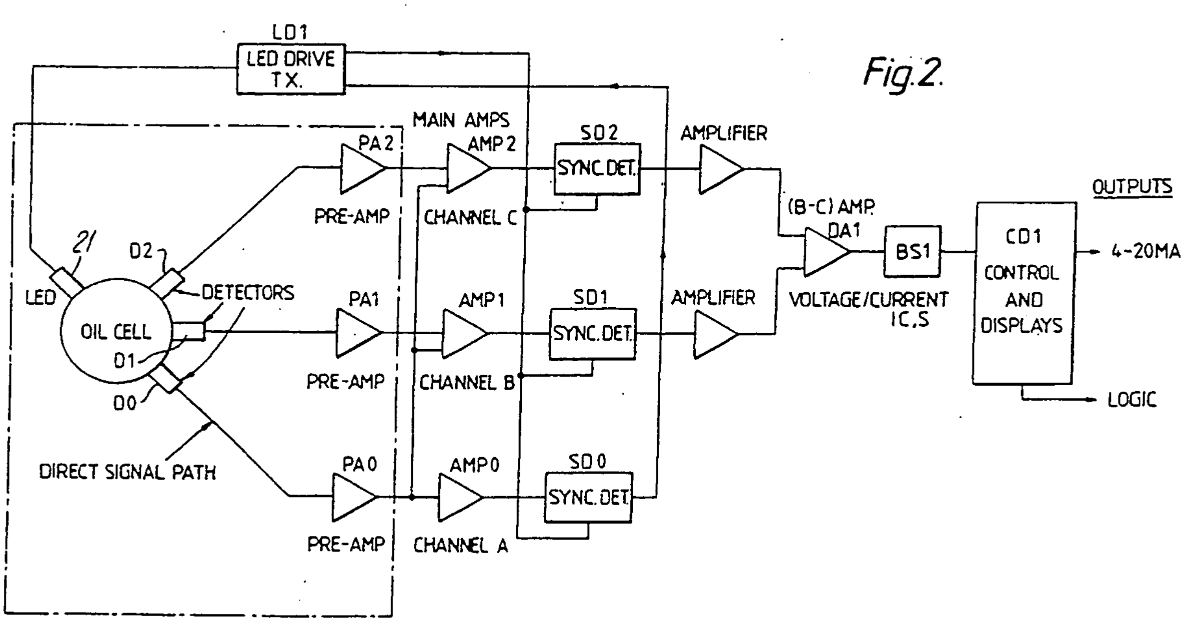

Fig.2.

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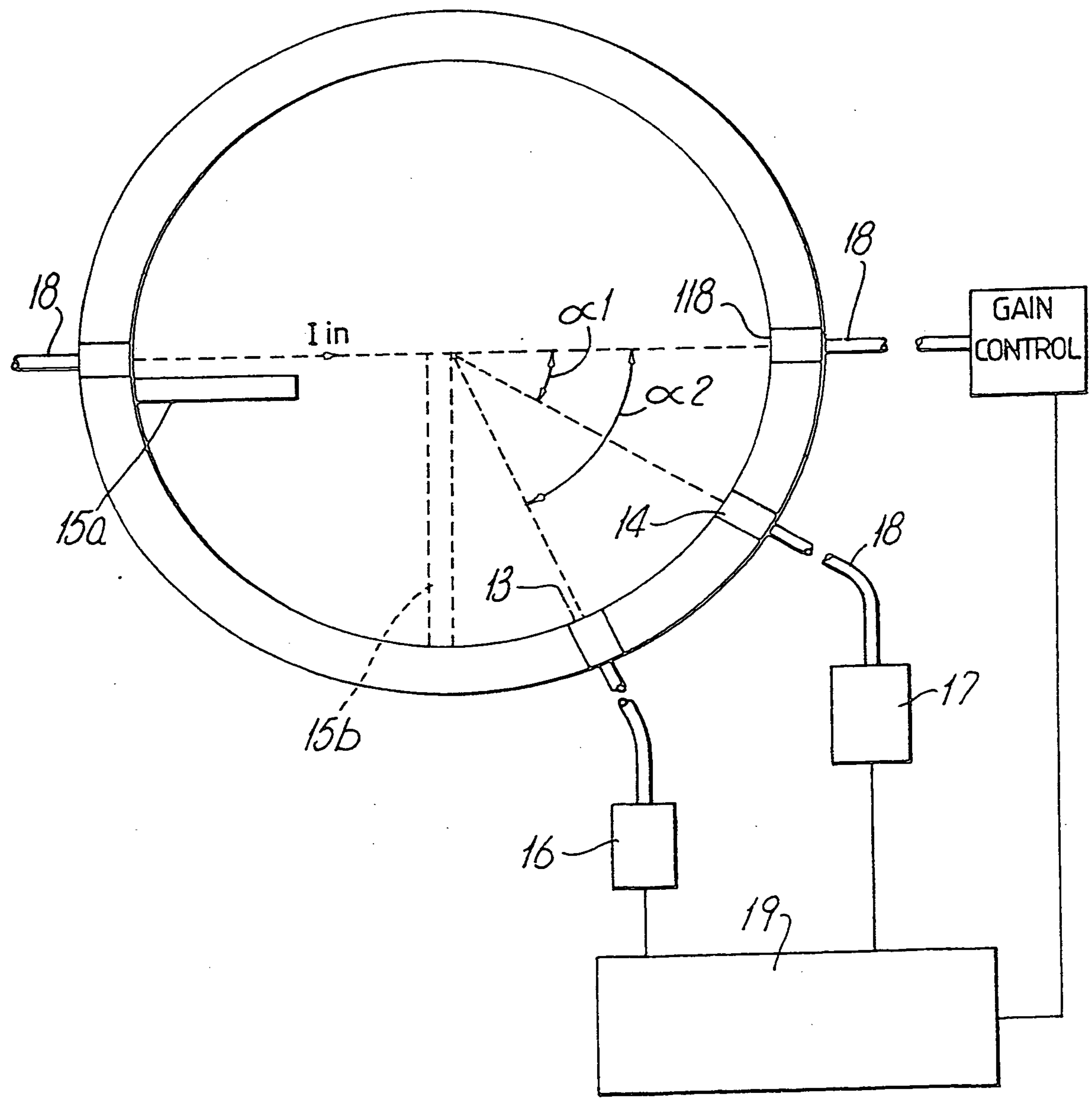
Fig.1.



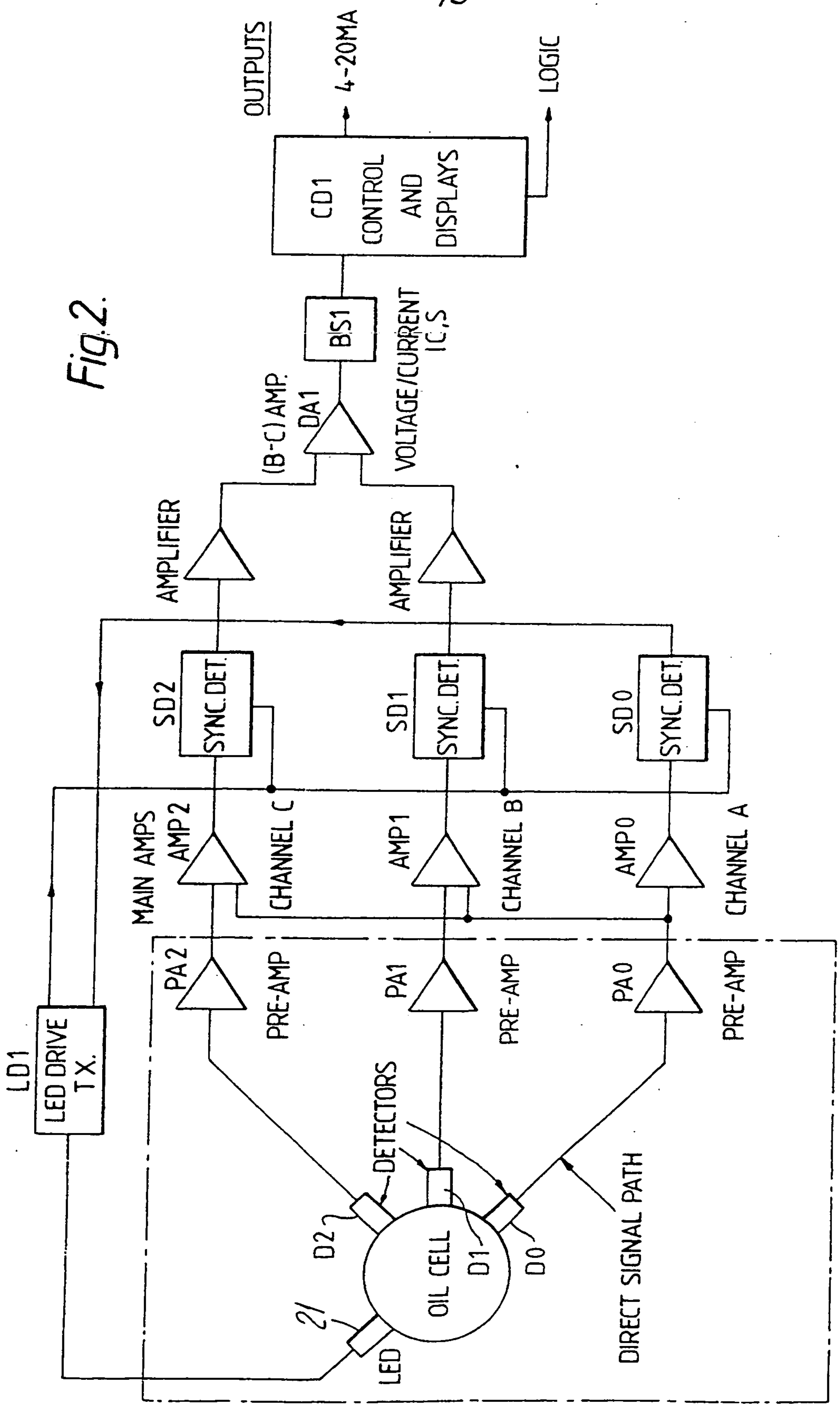

OUTPUTS
4-20MA
LOGIC
CD1
CONTROL
AND
DISPLAYS
BS1
VOLTAGE/CURRENT
IC,S
(B-C) AMP.
DA1
AMPLIFIER
AMPLIFIER
SD2
SYNC. DET.
SD1
SYNC. DET.
SD0
SYNC. DET.
MAIN AMPS
AMP2
CHANNEL C
AMP1
CHANNEL B
AMP0
CHANNEL A
PA2
PRE-AMP
PA1
PRE-AMP
PA0
PRE-AMP
LD1
LED DRIVE
T.X.
DETECTORS
DETECTORS
D2
D1
D0
OIL CELL
21
LED
DIRECT SIGNAL PATH

Fig.2.

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*Fig.3.*

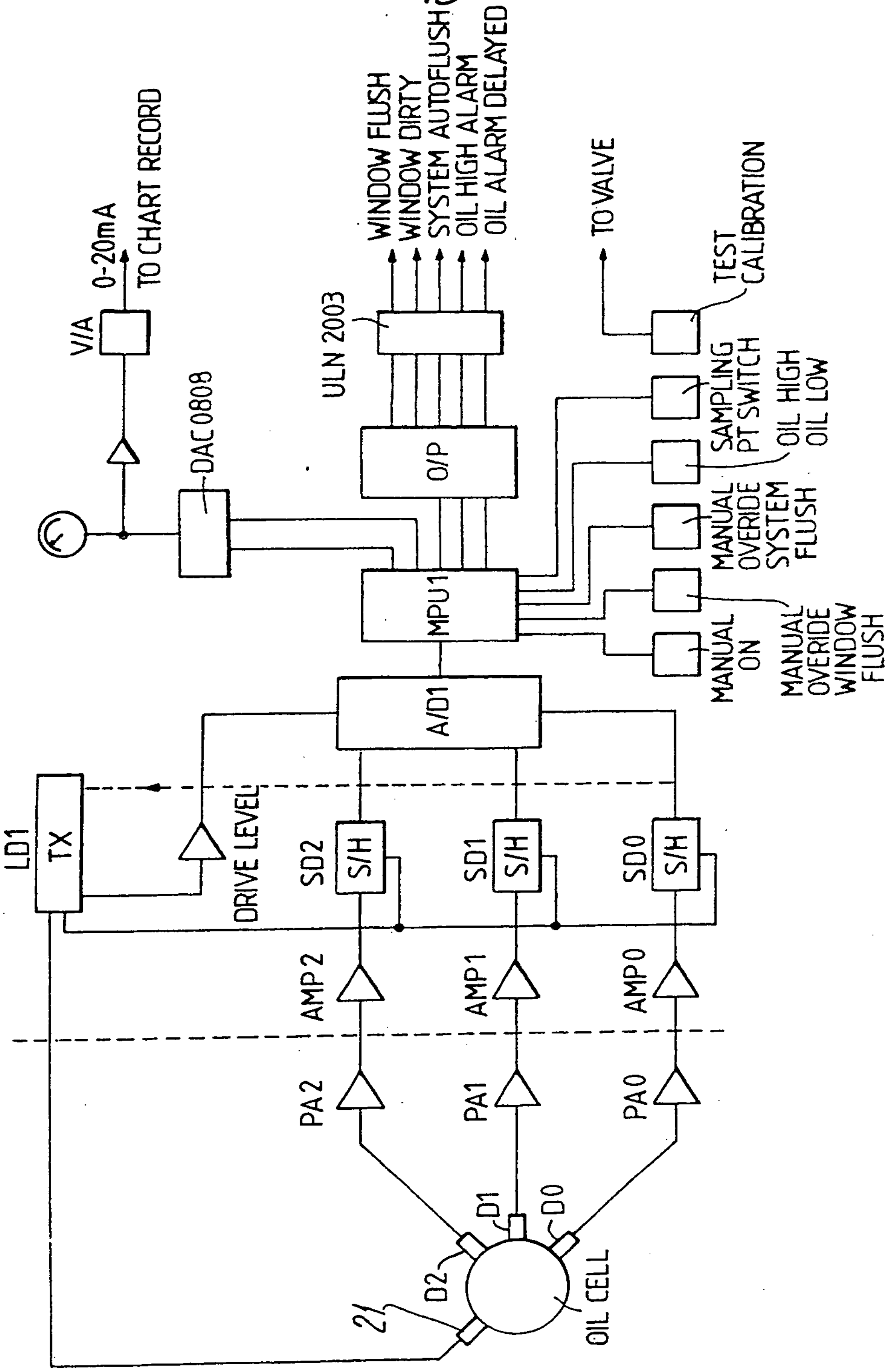

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Fig.4.

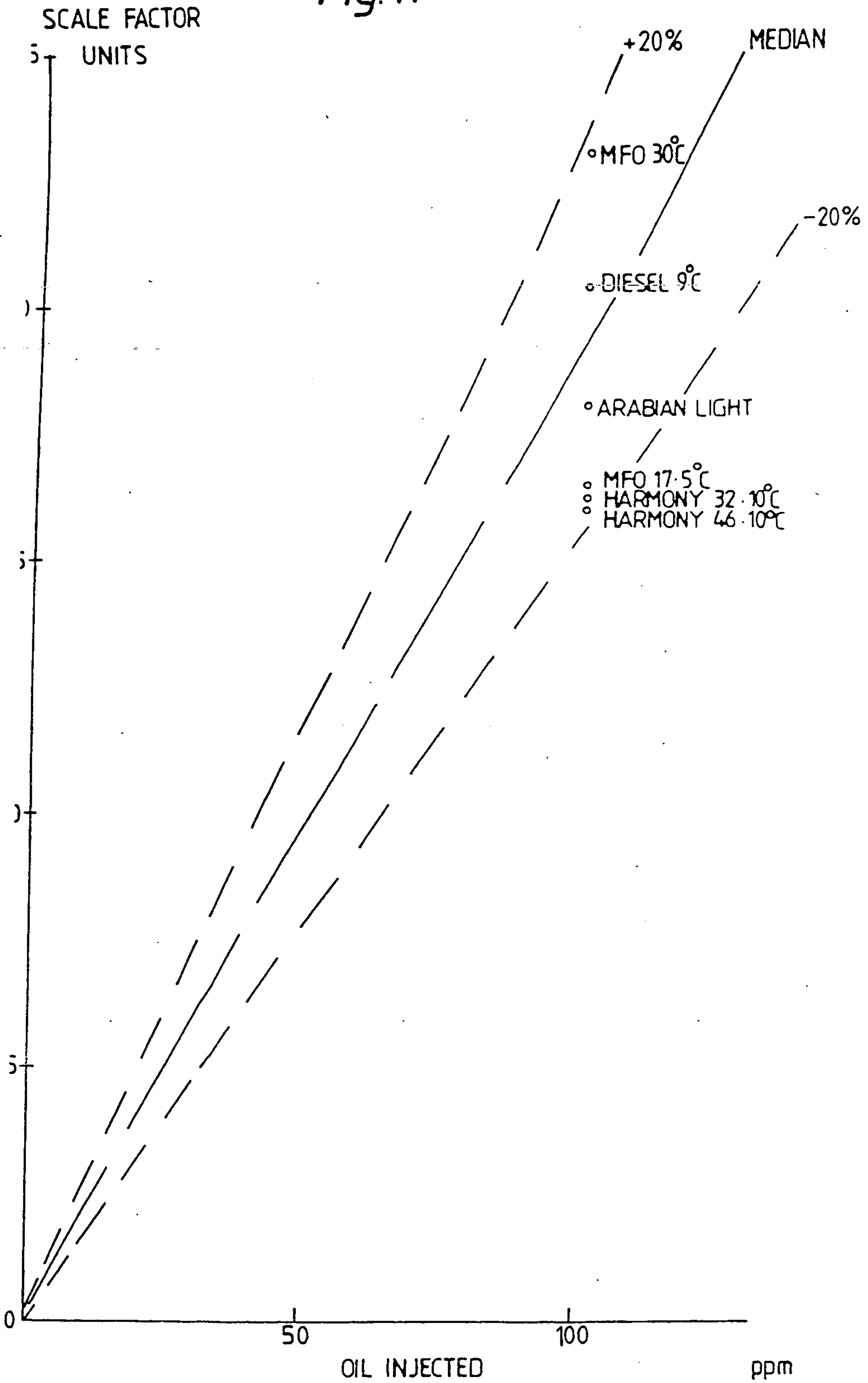

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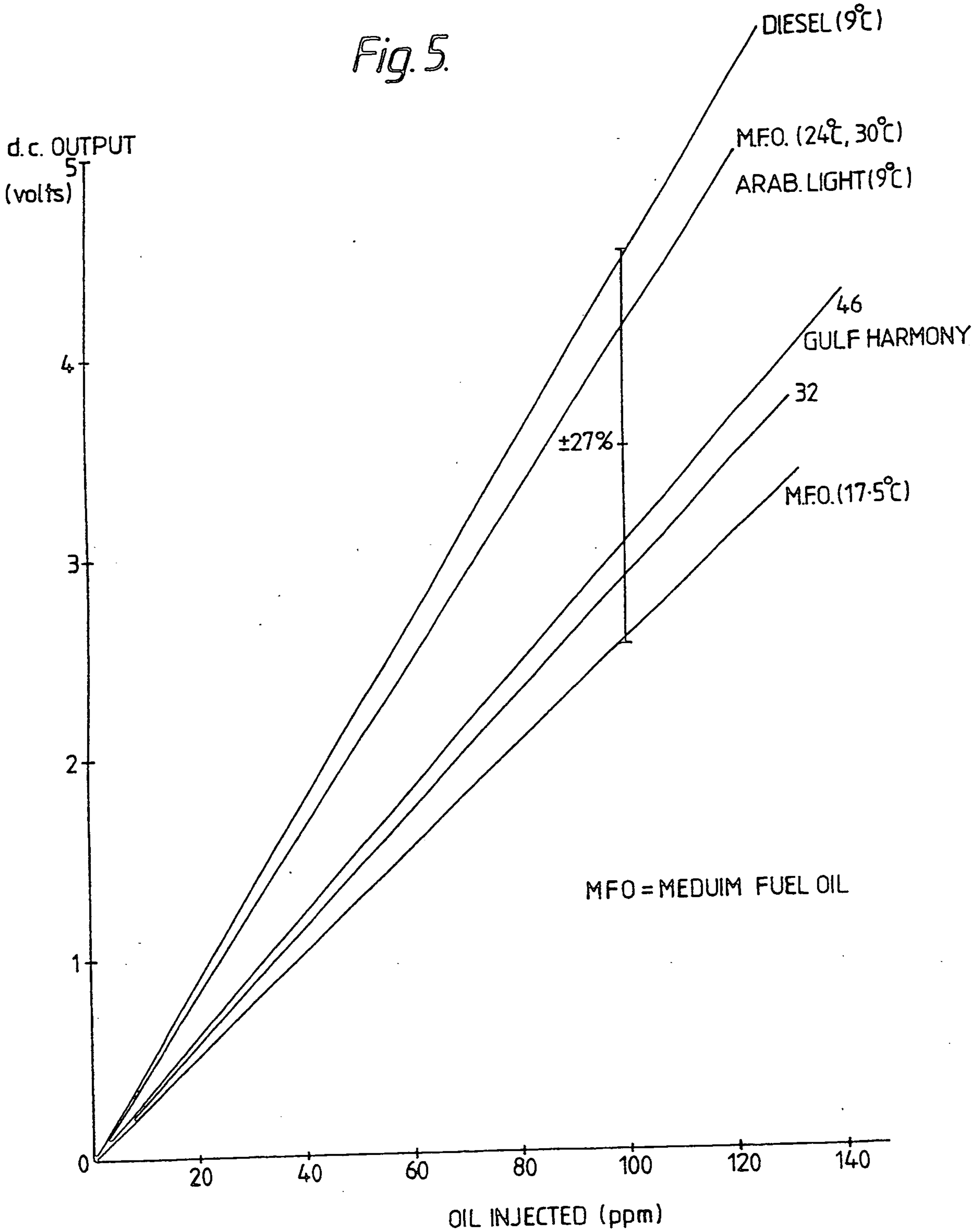
Fig. 5.



SPECIFICATION

**Det cting oil in water**

This invention relates to the detection of oil in water and in particular to detection arrangements for detecting and measuring different types of oils. Typically these arrangements are used in ballast and bilge monitoring operations on ocean going tanker vessels.

One of the problems in oil-in-water detection and measurement by the light scattering technique is the widely differing response characteristic of the range of oils that have to be measured. Not only should the detector employed be able to distinguish between suspended solid particles and oil droplets but it should also compensate for the speed in response of the different types of oils. Hitherto this has not been possible.

The intensity of light scattered by a suspension of an oil in water is a function of the scattering angle and has a maximum value at an angle determined primarily by the average size of the oil droplets, which in turn is determined by the oil viscosity. The viscosity range of both crude and refined oils is of course very wide, and is also temperature dependent, necessitating some form of recalibration when a single scatter angle cell is employed to measure different types of oil or the same oil at widely differing temperatures.

Our co-pending application No. 19046/78 (Serial No. 1,588,862) describes a dual angle scatter cell in which the light scattering angles are such that the effects of suspended solid scatter can be reduced from the oil reading. We have now found that, by a suitable choice of light scattering angles, signals can be obtained which, after compensatory computation, give an absolute value of oil concentration from a wide range of oils.

According to one aspect of the invention there is provided an oil in water detector arrangement in which oils are detected by their scattering effect on an incident light beam, the arrangement including two or more photodetectors disposed each at a different angle to the light beam, and means associated with the photodetectors for computing from the individual photodetector outputs the concentration of one or more oils suspended in water illuminated by the incident light beam.

According to another aspect of the invention there is provided a method of detecting and measuring oil pollution in water, the method comprising directing a light beam into an oil/water mixture, measuring the light intensity received at a plurity of angles to the incident light beam, and computing from the relative intensities of the scattered beams a value corresponding to the oil content of the oil/water mixture.

Embodiments of the invention will now be described with reference to the accompanying drawings in which:

Fig. 1 is a schematic plan view of the oil in water detector arrangement;

Fig. 2 shows in more detail the circuitry of the detector arrangement of Fig. 1;

Fig. 3 shows an alternative circuit arrangement; and

Figs. 4 and 5 illustrates the response of the circuits of Figs. 2 and 3 to various types of oil.

Referring to Fig. 1 the scatter cell of the detector arrangement comprises a housing 11, through which water carrying suspended oil may flow, and provided with an inlet window 12 for incident light and a plurality of outlet windows 13, 14 for receiving light scattered from the suspended oil. Typically the incident light beam is provided via an infra-red solid state laser (not shown) but an ZED or other light source may also be used. A baffle 15 may be mounted adjacent the window 12 to ensure that only scattered light reaches the windows 13 and 14. In some applications the baffle may be mounted perpendicular to the incident light beam as indicated by the reference 15*a* in intermediate positions.

Scattered light reaching the windows 13 and 14 is fed to respective photodetectors 16 and 17, preferably via optical fibres 18. Advantageously the scatter cell also includes a further output window 18 whereby the intensity of the incident beam may be monitored thus providing for computation for compensation of changes in that intensity.

The outputs of the photodetectors 16 and 17 are coupled to electronic circuitry, e.g. a microprocessor 19, programmed to compute an oil concentration level from the aboslute and relative values of the photodetector outputs.

We have found that the angle at which light is scattered from oil droplets suspended in water and the scattered light intensity depend primarily on the average droplet diameter and refractive index, which in turn is determined by the oil viscosity. Thus, for example, Diesel oil which is relatively light produces small droplets which scatter light through a relatively large angle whereas a more viscous medium fuel oil produces larger droplets which scatter light predominantly through a relatively small angle. It will be clear that each oil produces its own characteristic scattering intensity at each of the photodetectors and that, by comparing these two intensities, a measure of the oil concentration can be obtained. This technique also provides compensation for the lower intensity of light scattered by more viscous oils.

The difference in scattering response characteristics of different types of oils is illustrated by the following Example:–

Water containing an injected 100 parts per million of Diesel oil or medium fuel oil (MFO) was passed through a cell of the type shown in photodetectors disposed respectively at 17°, 30° and 38° to an incident gallium arsenide infra-red light source. The photodetector outputs were monitored for each type of oil, the results being summarised below.

The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

| Oil type | Detector Response Arbitrary units 17° | 30° | 38° |
|---|---|---|---|
| Diesel | 118 | 118 | 17 |
| MFO | 77 | 81 | 2 |

From the above it will be clear that by suitable programming of the circuitry coupled to the detectors an absolute concentration value for each type of oil can be obtained without individual calibration of the detector system.

By performing subtractions or rationing of the light scatter signals at the various scatter angles the concentration of each individual oil can be obtained. Thus the detector system requires only a single initial calibration and can then be used on all types of oil without further adjustment.

Cells with a perpendicularly mounted baffle 15*a* have been constructed having scattering angles 21 and 22 of 22.5° and 45° respectively and have been found to give good results with a wide range of oils. Typically we prefer to employ scattering angles 21 and 22 of 20° to 25° and 40° to 50° respectively. These scattering angles are given by way of example and are not to be regarded as limiting.

A square on rectangular cell could be used. Such a geometry allows for an array of detectors mounted opposite the source on a flat printed circuit board. Other cell cross sections can also be used.

Referring now to Fig. 2, this shows a typical circuit arrangement for calculating oil concentration levels from the outputs of the dual angle cell arrangement of Fig. 1. The cell outputs for scattering angles of zero, 21 and 22 respectively are fed via photodiode detectors D0, D1 and D2 to preamplifiers PA0, PA3 and PA2. These preamplifiers may comprise each a field effect transistor or an operational amplifier.

The outputs of the preamplifiers PA0, PA3 and PA2 are fed via amplifiers AMP0, AMP1 and AMP2 to respective synchronous detectors SD0, SD1 and SD2.

Light is injected into the scatter cell via a laser or an LED 21 driven in a pulsed mode by driver circuit LD1. Typically the light source 21 is operated at a low duty cycle, for example 2%, thus ensuring that the source has an extended lifetime. The driver circuit LD1 is coupled to the synchronous detectors SD0, SD1 and SD2 such that the detectors are enabled only when the light source21 is pulsed on.

The output from the synchronous detector SD0 associated with the direct light path through the cell is fed back to the drive circuit LD1 so as to provide an automatic gain control feedback loop whereby compensation is provided both from aging or drift of the light source and from oil fouling of the cell. This technique ensures that continuous calibration of the detector arrangement is effected.

The outputs of synchronous detectors SD1 and SD2 associated with the scattered light signals are fed to the respective inputs of a differential amplifier DA1 whose output comprises an analogue signal corresponding to the difference in intensity between the two scattered light signals. Although oil viscosity has a significant effect on the scatter profile of an incident light beam we have found that the difference signal obtained from scatter signals received at two suitable angle to an incident light beam is substantially independent of oil types.

Typically the differential amplifier output signal is fed via a buffer stage BS1 to a control and display arrangement CD1 which may include means for recording measured oil levels and for generating a warning signal when a predetermined oil level is exceeded.

The circuit arrangement shown in Fig. 3 is somewhat similar to that of Fig. 2 but employs digital processing techniques. The input circuit stages comprising preamplifiers PA0, PA1 and PA2, amplifiers AMP0, AMP1 and AMP2 and synchronous detectors SD0, SD1 and SD2 operate in a similar manner to the arrangement of Fig. 2 and need not be further described.

The outputs of the synchronous detector are fed via an analogue multiplexer to an analogue to digital converter A/D1 and a microprocessor MPU1 programmed to perform the computation of oil concentrations from the digitised detector output signals. The microprocessor output may be used to drive a variety of operating functions including cell flushing and water sampling. The microprocessor can also drive an output recorder and an excess oil alarm system.

Typically the microprocessor is programmed with an algorithm constructed e.g. to compensate for droplet-size variations in the fluid flow through the cell or to provide outputs giving an indication of droplet size distribution.

In an alternative embodiment a single synchronous detector preceded by a multiplexer may be employed. The single detector then feeds into an analogue to digital converter.

In further applications light scattering may be effected at three or more angles to the incident beam to provide further accuracy in the measurement process.

Figs. 4 illustrate the results obtained from the measurement of various types of oil using the circuits of Figs. 2 and 3. Fig. 5, which is included for comparison purposes, illustrates the corresponding measurements obtained from a conventional single angle scatter cell. In each case measured quantities of each type of oil were injected into a water stream flowing through the cell and the corresponding detector output response was determined. As can be seen from Figs. 4 and 5 the response spread from the various types of oils at an injected level of 100 parts per million is ± 27% for a single angle scatter cell (Fig. 5) but this spread is reduced to within ± 20% (Fig. 4) by using the double angle scatter techniques described herein. This respresents a significant improvement in accuracy over conventional techniques described herein suitable for bilge water monitoring applications without the need for recalibration for different oils.

The algorithms necessary for the computation process can also be partially dealt with using set

gains at different angles on the amplifiers, the ratios/values of these present gains being ptimised in prior experiments and tests. This opens up the use of such equipment for generalised measurements on 3 phase systems – e.g. for measuring oil/particles/water etc, and for filtering checking systems.

Typically the algorithm for a particular cell geometry is determined for measurements on known injected oil levels, the necessary techniques being known to those skilled in the art. Once a particular scatter cell has been calibrated in this way no further calibration is necessary.

CLAIMS

1. An oil in water detector arrangement in which oils are detected by their scattering effect on an incident light beam, the arrangement including two or more photodetectors disposed each at a different angle to the light beam, and means associated with the photodetectors for computing from the individual photodetector outputs the concentration of one or more oils suspended in water illuminated by the incident light beam.

2. An oil in water detector arrangement in which oils are detected by their scattering effect on an incident light beam, the arrangement including a cell wherein scattering of light from a pulsed light source is effected, drive means for the light source, a first photodetector disposed in alignment with the light source so as to receive light transmitted directly through the oil/water mixture, second and third photodetectors disposed respectively at first and second angles to the beam generated by the light source so as to receive light scattered by the oil/water mixture, synchronous amplifier channels are associated with each said photodetector and, in use, enabled when the light source is pulsed by the drive means, gain control means including a feedback loop from the first photodetector via the associated amplifier channel to the drive means whereby control of the light source intensity is provided, and means associated with the second and third amplifier channels whereby, in use, an oil concentration is calculated from the difference in the signals appearing on the two channels.

3. An arrangement as claimed in claim 2, wherein said calibration means includes a microprocessor.

4. An arrangement as claimed in claim 1, 2 or 3, wherein photodetectors are disposed one at a scatter angle of 20° to 25° and one at an angle of 40° to 50° to the incident light beam.

5. An oil in water detector arrangement substantially as described herein with reference to Figs. 1, 2 and 4 or Figs. 1, 3 and 4 of the accompanying drawings.

6. A marine bilge water monitor incorporating an oil detector arrangement as claimed in any one of claims 1 to 5.

7. A method of detecting and measuring oil pollution in water, the method comprising directing a light beam into an oil/water mixture, measuring the light intensity received at a plurality of angles to the incident light beam, and computing from the relative intensities of the scattered beams a value corresponding to the oil content of the oil/water mixture.

8. A method of detecting and measuring oil pollution in water, which method is substantially as described herein with reference to the accompanying drawings.

Printed for Her Majesty's Stationery Office by The Tweeddale Press Ltd., Berwick-upon-Tweed, 1982.
Published at the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.